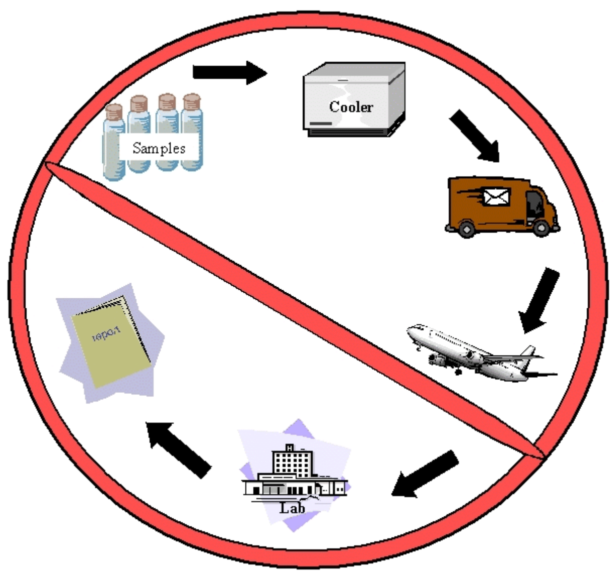
Early advances

Among its first activities OST focused on developing field analytical instruments which have proven invaluable for characterizing soils for Volatile Organic Compounds (VOCs), heavy metals, and radionuclides as well as for well-head groundwater analyses.

Expedited Site Characterization

These were then combined with the cone penetrometer and GeoProbe™ to facilitate subsurface characterization, and supplied with innovative decision support tools, culminating in Expedited Site Characterization (ESC). ESC emphasizes minimally intrusive technologies and optimized sampling. On-site analyses allow daily sampling location selection, reducing characterization time from months to weeks. The Argonne group instrumental in its development used ESC in characterizing the perched water zone at Pantex in 1995. ESC is now an ASTM standard practice.

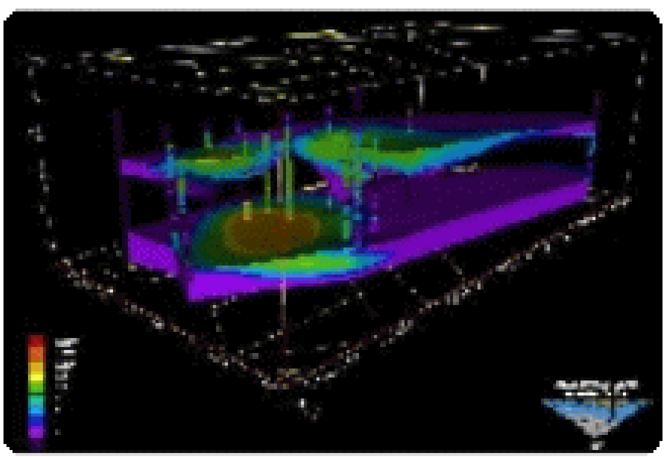


A related Ames Lab project focused on accelerating technology transfer. Contaminated sites were characterized using both current and new technologies; conclusions are given in the Innovative Technology Summary Report *Expedited Site Characterization* (TechID 77).

ERT and EIT

Electrical Resistance Tomography (ERT) and Electrical Impedance Tomography (EIT) are also aimed at improving subsurface characterization and monitoring. Projects have targeted subsurface imaging, tank leak detection, barrier validation, and DNAPL remediation monitoring, with an ultimate goal of non-invasive DNAPL mapping.

Next generation technologies



DOE sites continue to express high priority needs for improved characterization; these needs have evolved from initial field screening to final assessment applications. For example, several sites have expressed a need for real-time radionuclide and heavy metal characterization during soil excavation to determine when it is appropriate to stop. Similar needs involve waste sorting and separation based on radionuclide and/or heavy metal content.

Improved real-time subsurface characterization and monitoring techniques will be needed by 2006. The out-year focus will involve providing needed solutions for technology gaps identified in **APPENDIX A**. Prominent among these gaps is subsurface characterization of deep, hard-to-access areas beyond the reach of existing platforms. Integration of real-time characterization tools with excavation platforms and conveyor belt operations will be pursued as well to enable real-time differentiation of soil based on contamination by VOCs, heavy metals, and radionuclides.

Advanced characterization and monitoring research being conducted by EMSP and elsewhere will need to transition into full implementation. Promising sensing technologies under EMSP development include LIBS and electrochemical techniques for subsurface characterization of heavy metals and radionuclides; micro-electro-mechanical sensors (MEMs) with applicability for many contaminants of concern; and other new schemes for detecting radionuclides and heavy metals.

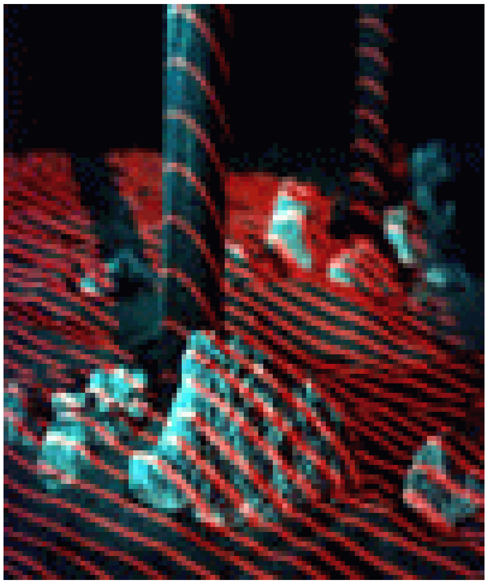
Alternative High-Level Waste Tank Disposition

New disposition approaches present characterization and monitoring challenges

VIP

Alternatives to HLW removal and processing

Removal, pre-processing, stabilizing, and shipping high-level tank wastes to long-term storage repositories present both substantial cost and technical risk. Accordingly, at this time DOE-EM is evaluating alternative scenarios for HLW tank disposition, including addressing the inherent risks associated with the waste residuals that may remain after the conclusion of retrieval operations. Aspects of these closure scenarios include assaying residual wastes for volume and composition, stabilizing residual inventory *in situ*, verifying and monitoring tank integrity, and leak prevention, detection, and mitigation.

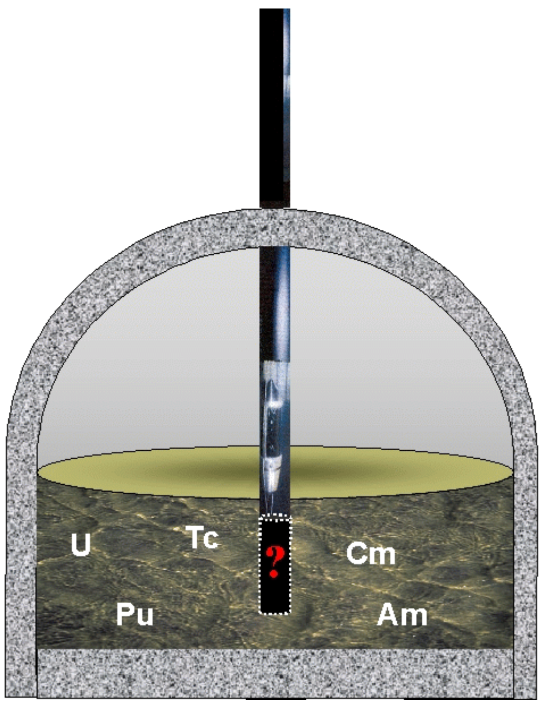


Characterization challenges

The total volume of any remaining wastes must be ascertained reasonably accurately as a start; techniques exist already, but refinement is needed. Estimates of inventories of radionuclides and other constituents will be required to support risk analysis modeling and to identify indicator species or parameters for long-term monitoring. This inventory estimation will be technically challenging due to waste heterogeneity, sampling access, and self-absorption. The physical integrity of the tanks themselves must also be determined. The nature and extent of any prior contamination outside of the tank may also be need to be determined.

Monitoring challenges

In the *in situ* stabilization scenario, improved methods for monitoring tank integrity will be needed for both single-shell and double-shell tanks. Current methods are cumbersome and time-consuming, and yet monitor only a small portion of tank wall surfaces.



Sensitive sensors and monitoring systems will be needed to provide early-warning detection of possible leaks from the tanks or migration of contaminants that may already have leaked. Moreover, as discussed elsewhere, sophisticated and credible modeling will be needed to support even a temporary *in situ* closure.

Topographic Measurement System

The Topographic Measurement System for measuring tank waste volume uses triangulated images of laser light to generate a map of the waste surface. This system is currently in use, although some further development is needed.

Pipe Explorer™ and robots

One approach to the inventory problem may involve further development of an existing OST-sponsored technology. In the Pipe Explorer™ system (TechID 74) an everted membrane is blown into a pipeline or duct. Gamma and beta radiation sensors are introduced directly; alpha radiation is detected by incorporating scintillating material into the membrane. Several strategies may be used to adapt this technology. The membrane can be blown through and beyond an opening into wider spaces where the gamma camera can be used. If the pipe opening is in a high radiation environment, added pipe lengths can reach a shielded location. Membranes and detectors can be extended into tanks when top access through risers or other penetrations is available. Sludge layers can be probed using everted membranes inside pipes with end slots or windows which can penetrate limited distances.

ERT

Electrical resistivity tomography has been developed for monitoring changes in subsurface conductance in tank farms (TechID 140). This could be coupled with the introduction of mobile ionic indicators into the grouts used for *in situ* waste stabilization.

Emissions Monitoring For High-Level Waste Processing

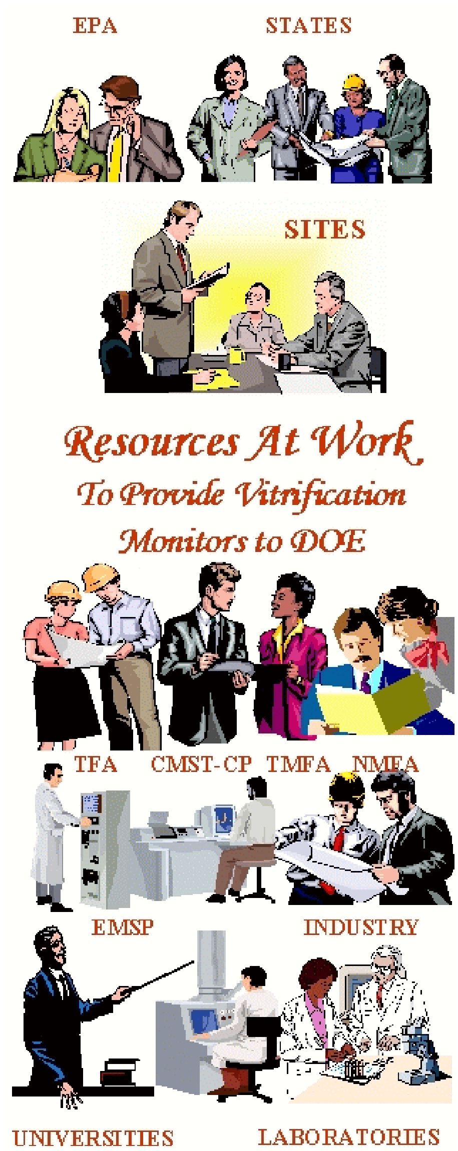
Crosscutting Leveraging at Work

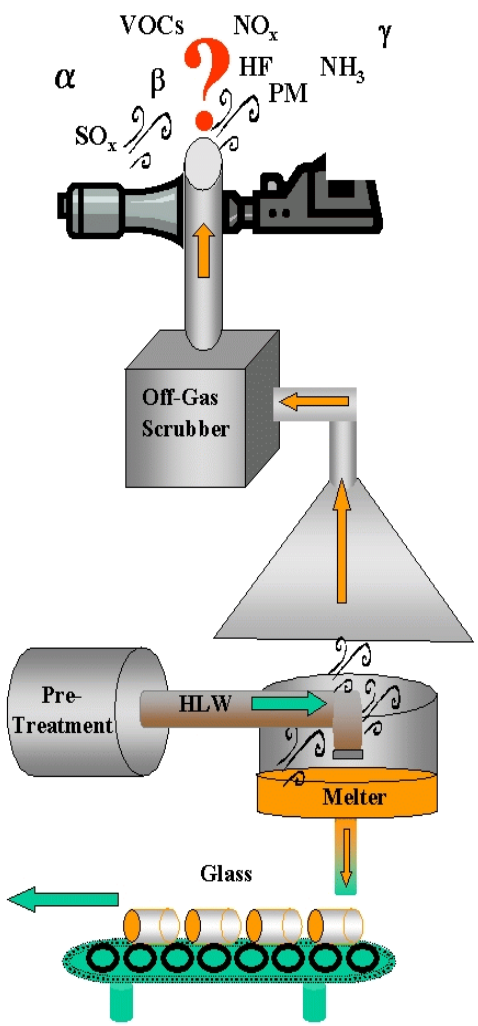
Off-gas monitoring for NO_x and other constituents during High-Level Waste (HLW) processing

Direct vitrification is a candidate treatment for sodium-bearing liquid wastes remaining in tanks at the Idaho National Engineering and Environmental laboratory (INEEL). As with other thermal treatment processes, an off-gas treatment system would be required for regulatory compliance; monitoring would be required for NO_x (NO and NO_2) and possibly also NH_3, CO, and/or H_2, depending on the NO_x removal process selected. Other thermal waste treatment processes at INEEL and other sites will require effluent monitoring for several hazardous constituents (radionuclides, toxic heavy metals, hydrocarbons, halogenated organics, and priority pollutants) for regulatory compliance. On-line monitoring of Hg, CO, NO_X, total hydrocarbons, particulate matter (PM), and other species will facilitate compliant operation and provide independent verification of process off-gas samples.

Technology development in DOE and beyond

The need for effluent monitoring extends beyond DOE tank waste concerns to other areas and, outside of DOE, to areas such as incineration, power generation, petroleum and metal refining, and chemical processing. Substantial technology development has been targeted at this wider need; commercial instrumentation is available for a number of applications. EPA sponsors the Environmental Technology Verification (ETV) program to expedite the acceptance and use of such instrumentation. The ETV program has verified technologies to monitor HF, NO, NH_3, and other compounds under simulated test conditions.





A pilot test of six commercial Hg monitors has been completed in collaboration with TMFA; the most successful will undergo Phase II testing at a commercial test facility. A TMFA program to test Continuous Emissions Monitoring (CEM) technologies supplements EPA efforts. Three commercial PM CEMs have been tested, and the development of dioxin/furan (D/F) monitors is part of a larger TMFA/EPA study of D/F formation and prevention.

Meeting the Site Needs

Given the advanced state of development and verification of CEMs, these INEEL needs are best addressed by adapting available technologies to site-specific functions, requirements, and conditions. Most relevant to HLW tank closure concerns is monitoring volatile off-gases produced when wastes are introduced into a melter. Adaptations of commercial instruments for use with off-gas systems should be given the highest priority, since such measurements are needed to design and qualify HLW vitrification processes.

A path forward previously identified is for DOE-EM to work with INEEL to develop function and design (F&D) requirements specifying the gases to be monitored, concentrations, and data and engineering requirements. Using these F&D requirements, INEEL would proceed to select a commercial monitor and identify a technology provider to install and demonstrate the technology in its planned pilot vitrification facility. DOE-EM could take the lead in developing and deploying both new and commercial technologies for these and additional constituents of concern; this would of course require keeping abreast of new developments in the CEM arena.

VIP

Understanding Natural Processes Affecting Contaminant Fate And Transport

Basic Science Challenges

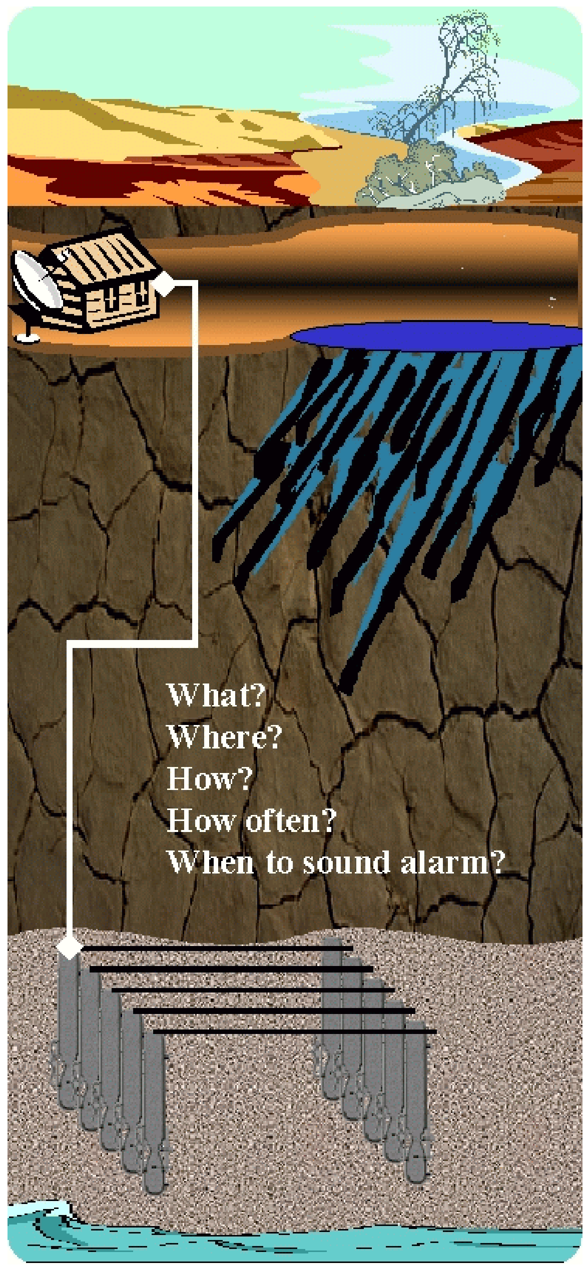
Reliable predictive models needed

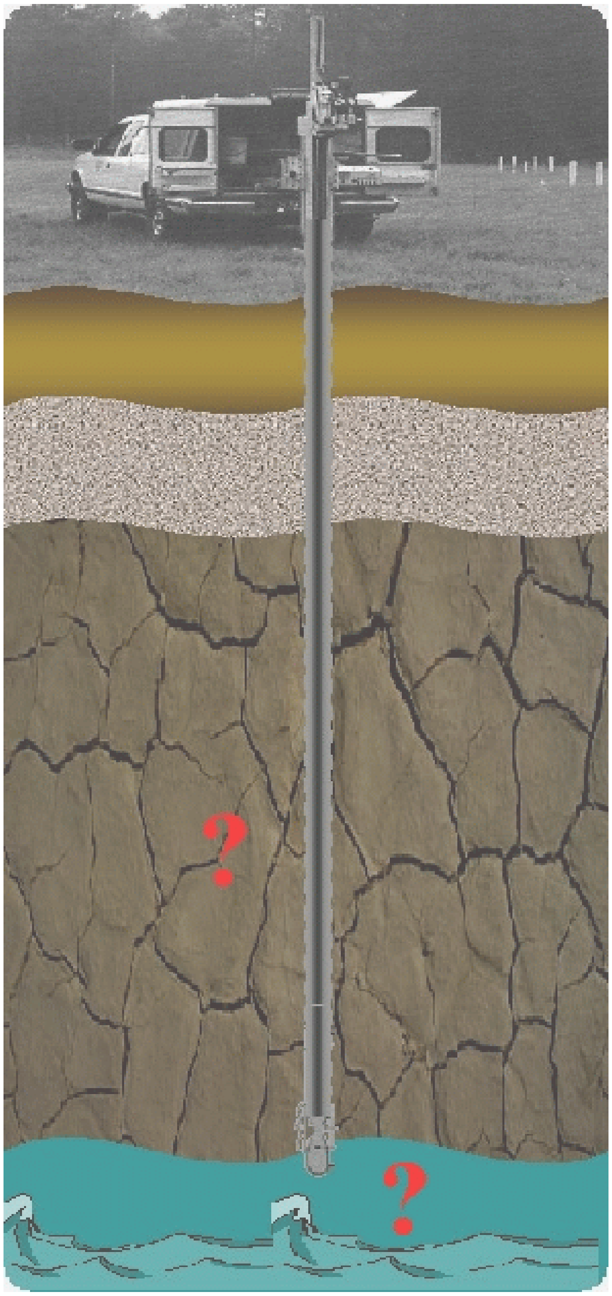
Reliable predictions of subsurface contaminant fate and transport are vital if DOE is to meet its Long-Term Stewardship obligations. Improved understandings of geological and geo-chemical processes, their relationship with contaminant fate and transport, and identification of key observables are critical; the National Research Council notes a current "inadequate understanding of ... characteristics that must be understood in order to make reliable predictions of fate and transport. ... little progress has been made on developing predictive models that incorporate the entire range of processes that may affect contaminant transport."

Every major DOE site identifies needs for defining the distribution of subsurface contaminants, quantifying their extent, and monitoring their movement. These needs were included by SCFA in its highest priority Work Package; related needs include improved understanding of permeability patterns, contaminant inventories, and vadose zone distribution and movement, along with better predictive models for groundwater flow and transport.

Previous studies

Previous OST projects have studied flow and transport in fractured rock, groundwater modeling, and data fusion for integrating diverse geophysical/ hydrological sources. EMSP studies have addressed transport of specific contaminants and development of geophysical techniques for subsurface characterization. EMSP studies of transport and soil fixation respond to high-priority Hanford and Oak Ridge needs.





Geophysical characterization tools

Many improved geophysical characterization techniques are being developed by EMSP, including very early time-domain electromagnetic, seismic, and radar techniques, along with combinations of these to provide high resolution subsurface mapping.

Fate and transport

Numerous research projects involving contaminant fate and transport are underway. These include identifying site needs for better ways to characterize physical, chemical, and biological properties of the subsurface, particularly in deep and complex geologic settings, as well as to characterize physical, chemical, and biological heterogeneity and develop more reliable migration prediction models. Additional collaborations include developing ways to integrate data on different spatial and temporal scales to improve estimates of contaminant and subsurface properties; incorporating complexities such as colloid formation, biological activity, and fractured rock transport paths into transport models; and conducting experiments and modeling studies of the interacting chemical, physical, and biological processes that determine contaminant fate and transport.

DOE-EM has supported geophysical characterization development since the inception of OST; some of the earlier work was similar to basic and applied research efforts now being conducted by EMSP. An efficient path forward in this critical area will be to pool all present and past DOE-EM-sponsored research efforts with activities underway in other agencies and at universities.

TechID 2237: Induced Fluorescence Sensor for Cone Penetrometer